REMOTE SENSING CENTRE

REMOTE SENSING TO ASSESS LAND USE / LAND COVER CHANGES AFFECTING THE DAUPHIN LAKE FISHERY

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ABSTRACT

A land use/land cover mapping project of the Valley River watershed was undertaken to quantify land use changes from 1948 to 1981 and to assess the implications of land use changes on the fishery resource. The study area included 1,786 square kilometers of land west of Dauphin Lake in southwest Manitoba. Thematic maps delineating eight cover types based on the Canada Land Inventory Classification System were produced by interpretation of 1948 and 1969 aerial photography and by digital analysis of 1980 LANDSAT data.

The study showed that by 1980 there was 63% more land under cultivation than there was in 1948, but 44% less woodland, 20% less pasture and 68% fewer wetland. Analysis of LANDSAT data was more effective in terms of labor cost and time than conventional airborne mapping techniques.

It is believed that land clearing and wetland drainage has resulted in increased peak discharges of the Valley River and a more rapid attenuation of flows after peak discharge during spring run-off. Rapid recession of water levels and increased flows are critical in low run-off years to walleye (Stizostedion vitreum vitreum) when spawning areas become de-watered or the larvae become stranded in the river without sufficient or preferred food sources. Land use changes are believed to have been less of an impact on walleye stream spawning than have channelization and drainage improvements. Those modifications have occurred to a lesser extent on the Valley River than on other Dauphin Lake tributaries, consequently the Valley River is now the main spawning stream for Dauphin Lake walleye.

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1. INTRODUCTION

The Department of Natural Resources of the Government of Manitoba and the Department of Energy, Mines and Resources, Government of Canada, have, by means of a Memorandum of Understanding, entered into a joint remote sensing Technology Enhancement Program (T.E.P.) in 1982 (Appendix I). The purpose of the program was to demonstrate the value of remote sensing technology in managing Manitoba's natural resources. Participating agencies also had an opportunity to broaden their knowledge in this technology. The program involved the use of a DIPIX Digital Analysis System (ARIES II)[1] on loan from the Canada Centre for Remote Sensing (C.C.R.S.). The equipment was put in place at the Manitoba Remote Sensing Centre in December, 1982 and remained until the duration of the agreement in March, 1984.

In response to an invitation to participate in a demonstration project for resource mapping, the Manitoba Fisheries Branch proposed a land use/land cover study of the Dauphin Lake fishery. The Valley River watershed was selected for study because, in comparison to other Dauphin Lake tributaries, it is the main spawning stream for Dauphin Lake walleye (Stizostedion vitreum vitreum). Also, the watershed has undergone the least amount of physical alteration and channelization in the riparian zones and river proper. In comparison to all other Dauphin Lake tributaries, the Valley River has the lowest sediment input per unit of watershed area (Penner 1982). The study of that fishery was initiated in response to the rapid decline in the fish production of Dauphin Lake since the high levels obtained in the 1940's and 1950's (Fig's. 1 and 2). Declines in fish production, particularly that of walleye (Fig. 3), appeared to be related to poor spawning success in streams emptying into Dauphin Lake and directly or indirectly caused by: 1) stream channelization, 2) land clearing and wetland drainage, and 3) physical obstructions to fish during spawning migrations.

1.1 Objectives

The objectives of the land use/land cover mapping project were to: 1) provide detailed thematic maps and area values for each land use/land cover type in the Valley River watershed for the years 1948, 1969 and 1980;

1. The mention of a company name does not imply endorsement of the product.

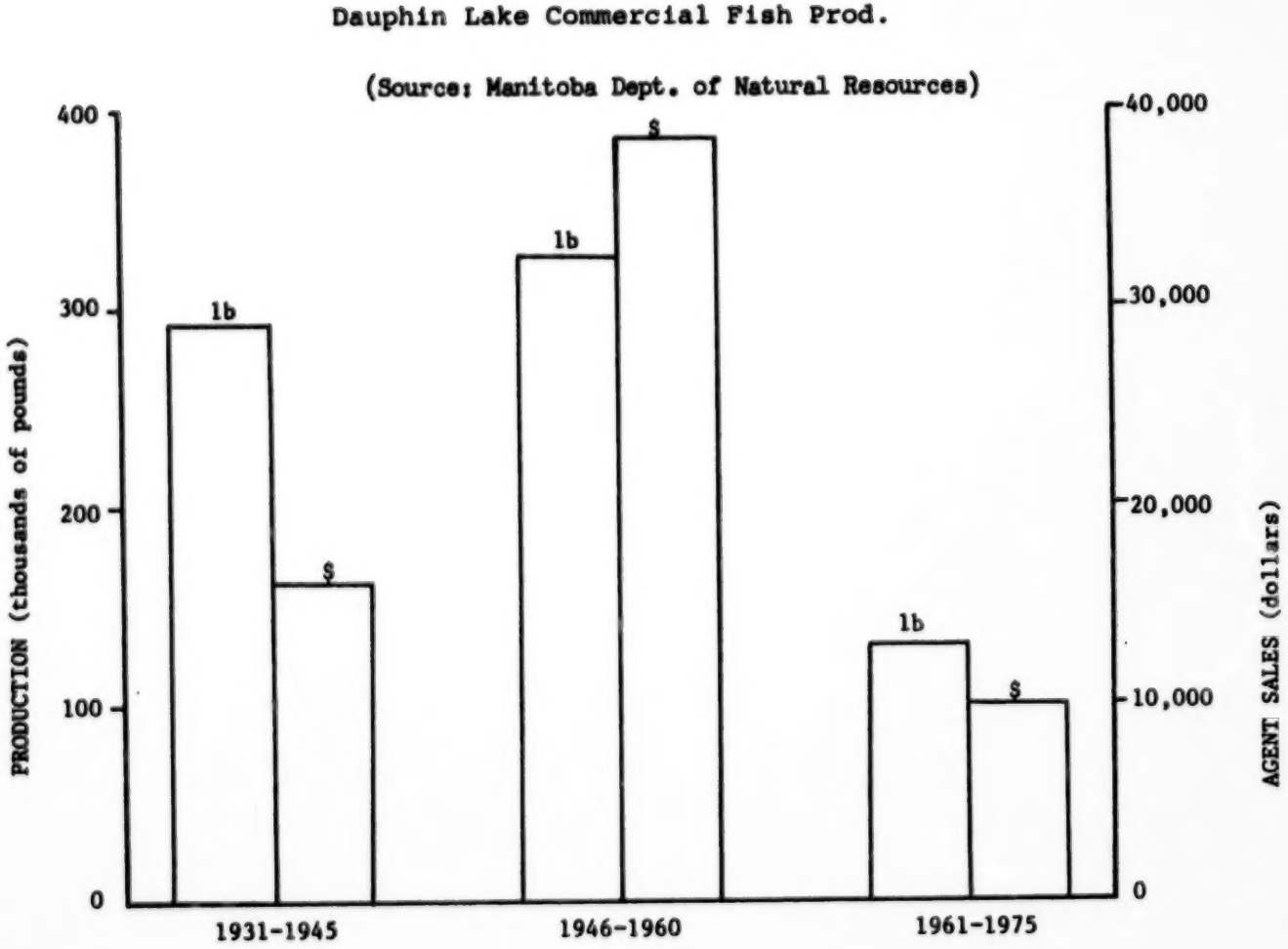


FIGURE 1: Average Annual Production for each 15 yr. Period Since 1931

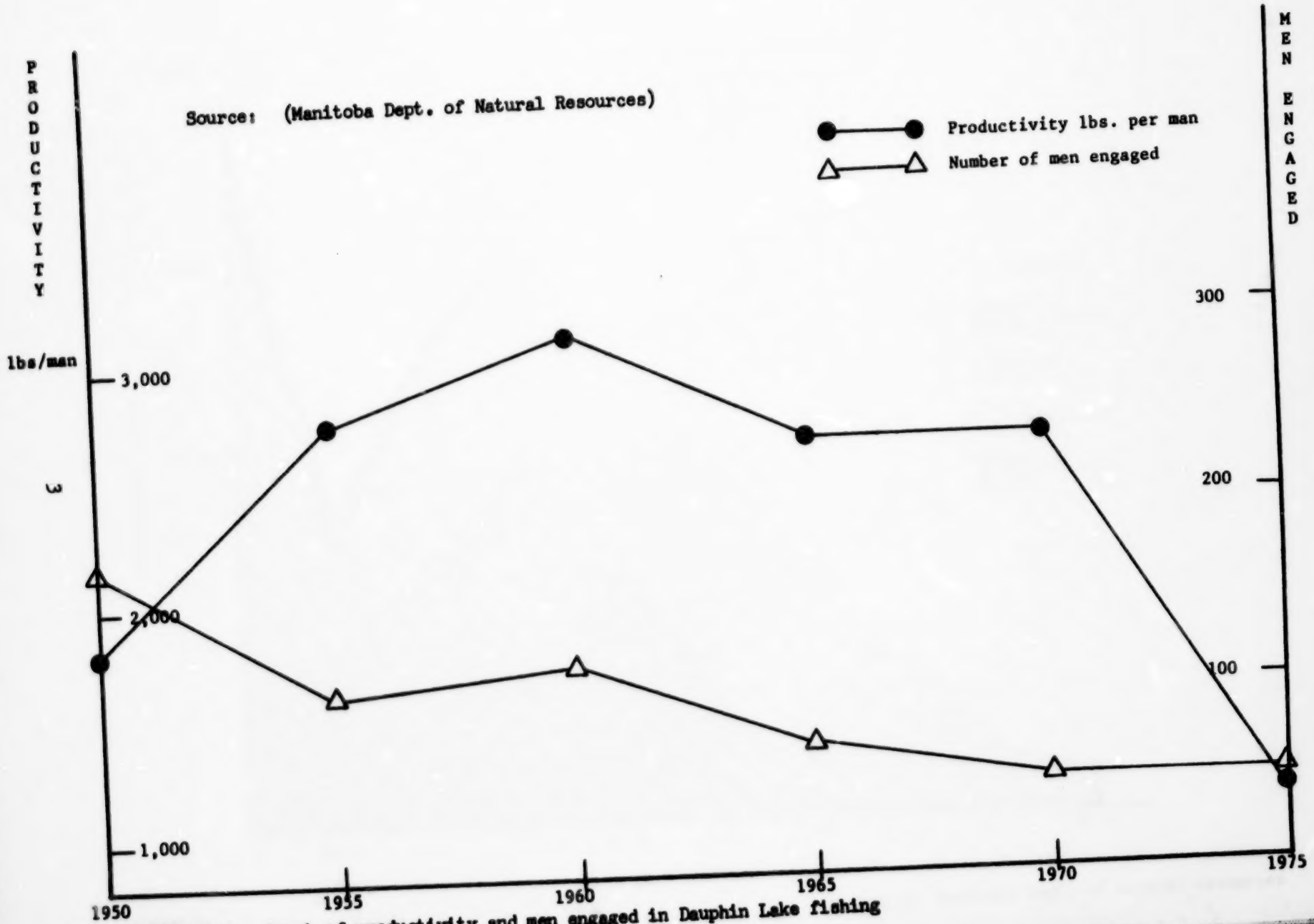


FIGURE 2: Graph of productivity and men engaged in Dauphin Lake fishing

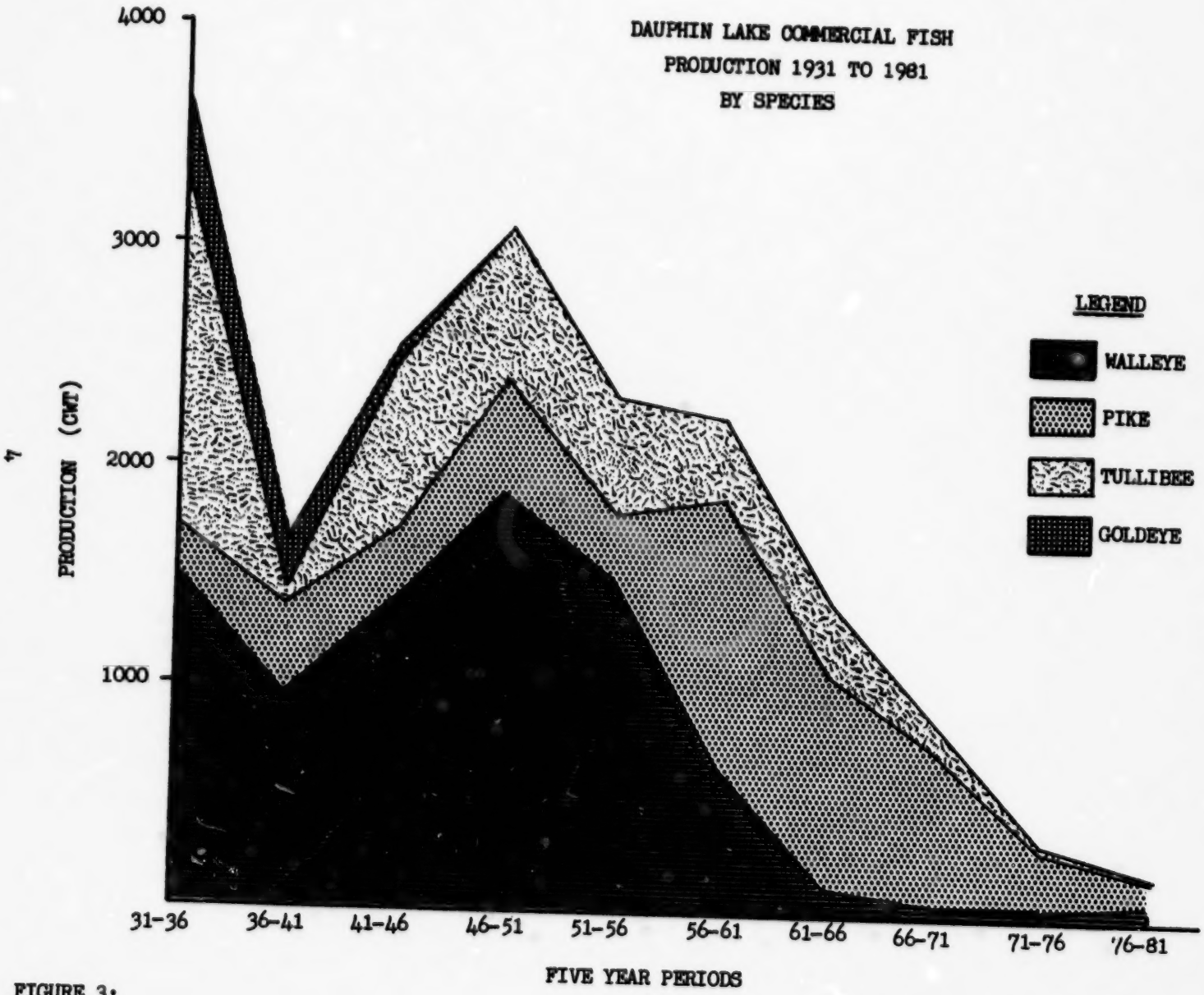


FIGURE 3:

Source: Manitoba Dept. of Natural Resources

2) examine and compare cost, time and accuracy factors of land use/land cover mapping using LANDSAT digital data and conventional airborne data:

3) demonstrate the usefulness of remote sensing techniques for fisheries management; and,

4) assess the implications of land use changes and present land use activities upon the fisheries resource.

2. THE STUDY AREA

2.1 Location and Description

The 1,786 km^2 study area was located 230 km northwest of Winnipeg between the southern foothills of the Duck Mountains and the northern portion of Riding Mountain Park and west of Dauphin Lake (Figure 4). Dauphin Lake is approximately 536 km^2 in area and has a maximum depth of 5 metres. The seven major inflowing streams originate in the rugged Duck or Riding Mountains of glacial drift and flow down a sloping plain of clay and loam interspersed with gravel ridges (McLeod and Moir 1944). Stream origins, with elevations of up to 700 metres fall to an elevation of 260 metres at Dauphin Lake. Mossy River is the lake's only outlet.

Agricultural development in the area began in the 1800's with the most readily accessible land being occupied by 1900.

2.2 Surface Geology and Soils

The Duck and Riding Mountains are part of the Manitoba Escarpment which is believed to be the ancient shore of Lake Agassiz. Ehrlich (1959) described the study area as occupying parts of the Lowland Plain and the Valley River Plain. The Lowland Plain starts at Dauphin Lake and is bounded on the West by a prominent beach ridge of former Lake Agassiz (the present position of Highway 10). Surface deposits within the area consist of a ground moraine, thin outwash and lacustrine deposits, and recent alluvial sediments. The topography is undulating with low ridges and shallow swales trending in a north-south direction.

The Valley River Plain which continues west from the Lowland Plain, occupies a former bay of glacial Lake Agassiz between the Riding and Duck Mountains.

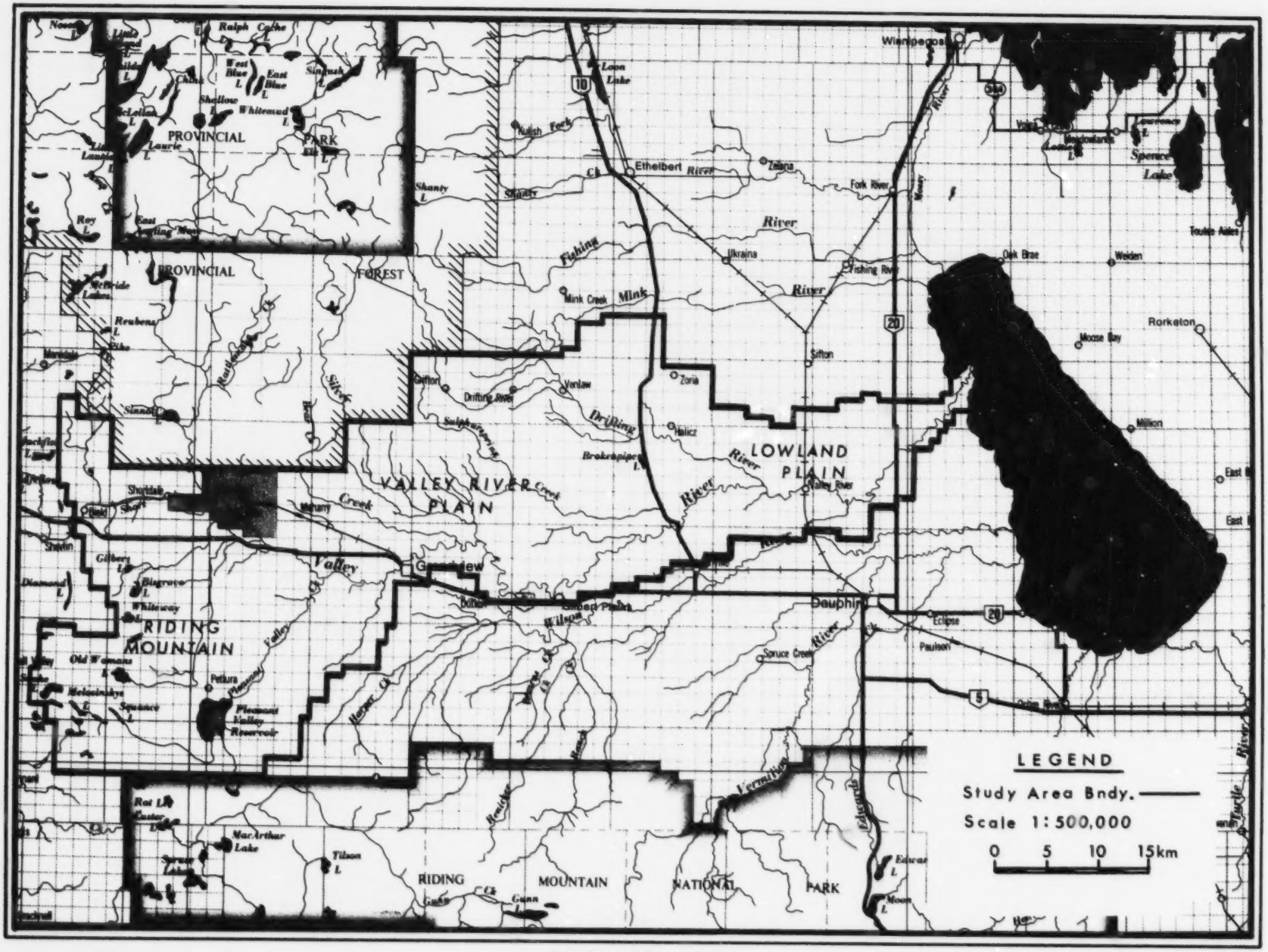
The surface deposits in the axial portion of this plain are lacustral sand, silt and clay sediments.

The peripheral area is occupied by a ground moraine of boulder till and lake-washed boulder till deposits. The topography of the Valley River Plain is smooth to gently sloping over most of the area and the soils are predominantly well drained.

The Canada Land Inventory Soil Capability maps (1968) show that the soils of the study area are typically class 2X and class 3-4 with some soil and topographic restrictions. Soils in class 2 have moderate limitations that restrict the range of crops or require moderate conservation practices. Classes 3 and 4 have moderately severe to severe limitations on the range of crops and productivity.

2.3 Vegetation

The reconnaissance soil survey shows the study area occupying the Aspen-Oak Section, extending westward from Dauphin Lake to the Town of Grandview, includes the southern part of the Lowland Plain and most of the Valley River Plain. Aspen (Populus tremuloides), is the most prevalent species with stands ranging from small clumps through large groves to continuous heavy-growth associations. Some ash (Fraxinus pennsylvanica), Manitoba maple (Acer negundo L.), and occasional elm (Ulmus americana L.) are found on alluvial soils along streams (Oswald & Nokes, 1979).



STUDY AREA MAP

FIGURE 4

3. METHODS

3.1 Data Acquisition

Black and white aerial photographs of the study area were acquired for 1948 and 1969 at scales of 1:15,840 and 1:50,000 respectively. A 1980, August LANDSAT cal. 3 computer compatible tape (CCT) of track 36 frame 24 was also obtained. Aerial photography taken in 1981 (scale 1:15,840) was used as training data for classifying the LANDSAT image and for digital mapping accuracy assessments.

3.2 Land Classification

Classification of the land areas on the 1948 and 1969 aerial photographs and the 1980 LANDSAT image were based on the Canada Land Inventory system to provide information at the reconnaissance level (Hodgson, 1973). Eight land cover types were selected for classification (Table 1).

TABLE 1

LAND CLASSIFICATION SYSTEM: VALLEY RIVER WATERSHED

Classification Code		Description
A:	Agriculture	All land in cereal crops and sown forage crops
W:	Woodland	Includes deciduous and conifer classes (productive and non-productive)
S:	Summerfallow	Tilled fields bearing no crops
P:	Pasture	Improved grazing and/or hay cutting areas (native grasses)
K:	Rough Graze	Rough, unproductive areas which may be used for grazing. May contain up to 25% scrub bush.
WL:	Wetlands	Low lying areas and fringes of lakes supporting aquatic vegetation
L:	Lakes	All open water bodies
U:	Urban	Town locations

3.3 Air Photo Interpretation

Initially, the photo interpreters were assigned a common test area which each classified according to a key (Table 1). Comparisons were made between each interpreters results in order to assess the continuity of interpretation. Problem areas were discussed and where necessary, modifications were made to the photo interpretation key.

3.4 Data Transfer and Planimetry

Approximately 750 aerial photographs (scale 1:15,840) taken in 1948 were interpreted. The data were transferred to a unified mylar map base using a K & E enlarging projector. Alignment of the photo data to the mylar base was accomplished by matching the section roads which had been precisely scaled on the mylar base map. Transfer of the photograph interpretation data onto these planimetric maps was necessary to remove tilt, tip and scale changes in the photography which then allowed accurate area calculations to be made.

The 1969 photo interpretation was performed on 1:15,840 rectified photo enlargements produced from the 1:50,000 scale imagery. Each enlargement covered up to 50 km^2. Land cover types were drafted directly onto these prints. This procedure avoided the time consuming process of data transfer to base maps.

Area calculations of the various photo interpreted cover types were analyzed with an electronic planimeter. Statistics by section, township and range for both years of aerial photography were entered into a computer which was programmed to calculate area change.

3.5 Digital Analysis

The LANDSAT image was analyzed with a DIPIX ARIES II digital analysis system on loan to the Manitoba Remote Sensing Centre from the Canada Centre for Remote Sensing. Both supervised and unsupervised classification techniques were tested. The methodology of Digital Image Processing (DIP) followed is summarized by a flow chart in Figure 5.

The DIP procedures can be divided into four groups according to their tasks:

1) geometric rectification of LANDSAT multispectral data;
2) supervised and unsupervised classification;
3) post classification filtering and thematic map production;
4) planimetry of classes.

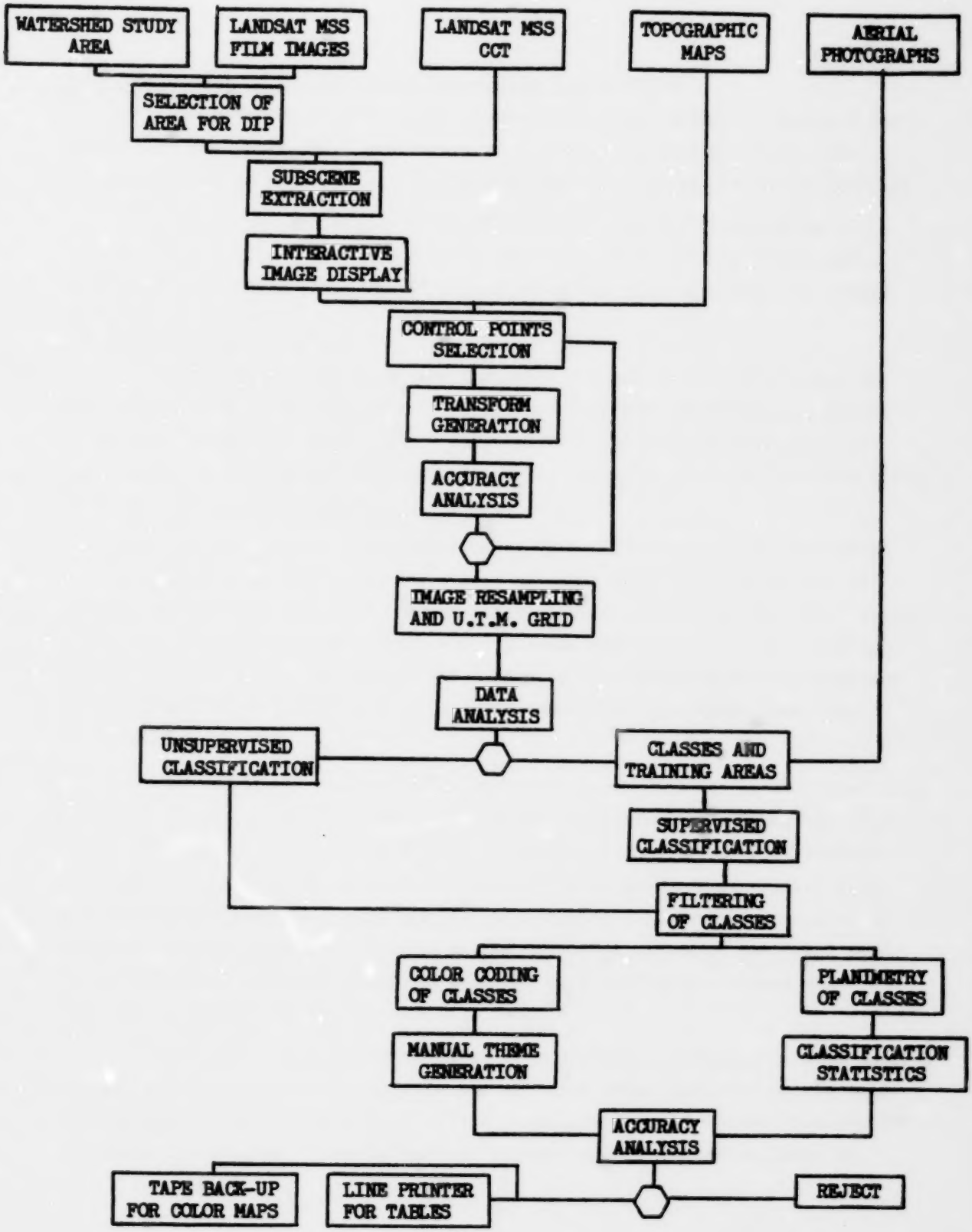


FIGURE 5 Flowchart of interactive digital image processing (DIP).

3.6 Description of Digital Image Processing System ARIES

The advanced digital image processing system, ARIES, is designed for interactive, computer-aided processing of digital multispectral data. The system consists of a DEC PDP-11/23 computer and color image display peripherals.

Image data are stored in a 200-megabyte disk and displayed on a Hitachi color T.V. monitor with interactive graphics capability under cursor control on a graphics pad. The displayed scene can also be roamed and zoomed.

3.7 Geometric Corrections

The standard geometric and radiometric corrections were applied to the data as part of the CCT generation process completed at the Prince Albert Satellite receiving station. These corrections rectify gross geometric distortion in the raw LANDSAT multispectral data. However, residual position error of up to 10 km still remains.

LANDSAT computer compatible tapes with precise geometric correction and rectified to the Universal Transverse Mercator Grid (UTM) system may be ordered in the form of a DICS product (Digital Image Correction System). Those tapes cover one quarter of a 1:250,000 scale map sheet and cost considerably more to produce than a full scene CCT. Because the project area was large and straddled map sheet boundaries, a computer compatible tape was chosen over DICS products.

In the study, the precision geometric correction was accomplished with the ARIES system using the image registration and resampling software package. Using 1:50,000 scale topographic maps, 22 control points evenly distributed over the study area were selected and identified on the LANDSAT digital data. UTM coordinates were then read from the topographic maps for these points and entered into the computer. Because of the extensive system of sectional roads in the area, all the control points selected were road intersections which are very easily identified on the satellite image.

The line and pixel coordinates were obtained automatically when control points were located with a cursor on the enlarged image displayed on the color T.V. monitor. Coefficients of an affine transform were calculated from the UTM and image coordinates. This polynomial transformation yielded an image to

grid registiation with an error of less than 50 meters.

The resampler program was run next and the original pixels (nominal ground resolution elements of 59 m x 79 m) were resampled to 50 m x 50 m. Furthermore, the LANDSAT scene was reformatted to correspond to the coordinate grid of the topographic maps.

3.8 Scene Classification

The scene classification included both unsupervised and supervised classification of a single-date LANDSAT subscene.

The ARIES II unsupervised classifier does not use field data for the determination of class statistics. Instead, it forms a histogram and identifies its spectral peaks from the multiband input data set. From the histograms of each band of data, a maxima table is calculated which shows the statistical parameters (mean values and standard deviations) for each peak. These values form the statistics for each class which can vary from 1 - 32 (classes). With ARIES, the number of categories (peaks) can be lowered by increasing the multiplier of standard deviation (merge factor). With the operator choosing the desired number of these classes, the computer will calculate the necessary merge factor from the maxima table. For example, a maxima table may be reduced from 28 classes down to 12 classes by this grouping technique. The fewer number of classes chosen, the more likely it is that similar ground features will be merged into a common class. In order to provide maximum separation, 16 classes were chosen from which signature files were generated. It is common practise to choose more classes than are required and then to manually merge classes where necessary at a later time.

A maximum-likelihood classification was performed using these computer generated signature files. ARIES software allows for post classification class merging or separation should the initial trial classification not prove satisfactory. Difficulty was experienced in establishing the same eight classes as used in the photo interpretation when the unsupervised techniques were applied. Confusion arose between rough graze and woodland, as well as improved pasture and croplands. As a result, the technique was abandoned in favor of supervised training.

The supervised maximum - likelihood classification requires knowledge of the training areas (field data), from which the statistical parameters for each class can be determined. Aerial photographs taken in 1981 at a scale of 1:15,840 were used to identify ground features for the supervised LANDSAT image classifications. A number of locations of each cover type were identified throughout the study area. The ARIES software then calculated the parameters for the mean spectral vector, representing the class average value in multi-spectral space and the covariance matrix, which is a measure of class dispersion. Calculations of the normal probability density functions are based on these two parameters. They approximate the data distribution in respective classes, thus providing models for sorting image pixels into the class to which they most probably belong (Kalensky, Moore, Campbell, Wilson and Scott, 1981). This procedure is known as the maximum - likelihood classification rule.

Eight mapping classes were selected which coincided with the eight photo interpretation classes used for the 1948 and 1969 data. Initially, small test areas were classified and the results were compared to the 1981 aerial photography check data. Problem areas in the classification were noted. With the aid of scattergrams of the training areas produced from band 5 and band 7, a procedure known as "training area purification" was employed. This procedure can remove much of the spectral overlap between class statistics. Modified signature files were then generated and used to classify the entire project area.

Post-classification filtering of the image was performed to eliminate small scattered pixel groups resulting from spectral anomalies located in broader, more homogeneous cover classes. The post classification filtering program allows the operator to specify minimum size groups of pixels representing any theme which shall be allowed to remain. Groups smaller than specified, will be included in the larger, overall theme in which they lie. The "eat-in-depth" for these scattered pixels (which is a measure of how far into a more pure theme that scattered pixels may be changed) can also be specified. This technique removes the speckled effect which would normally occur in an unfiltered thematic map production. See Appendix II (color thematic map of the 1980 digital classification results).

3.9 Planimetry of Classes

The planimetry of classes can be applied to classification results. The ARIES computer software permits automated computation of class (theme) areas inside any specified polygon. In this case, the total study area was sub-divided into nine watersheds (polygons). Each were identified by drawing its boundaries on the T.V. monitor using the write function of the interactive graphics pad.

The areas of the final classification results coinciding to the interior of each watershed were then computed.

Results were printed in tabular format on a line printer. The number of classes (themes), counts of pixels for each class, hectares and percentage of the respective class in the watershed were all listed.

Because the ARIES II image analysis system uses a pixel count procedure to calculate the areas, the results of the planimetry were extremely accurate, providing the operator carefully identifies the boundary of the desired area. In this case, the planimetry results differed by no more than 3% when compared to the actual ground survey figures.

4. RESULTS

4.1 Land Use Changes

Land use changes in the 1,786 km^2 study area are illustrated in Figure 6. Cultivated land increased dramatically from 37% in 1948 to 60% in 1980. All other categories decreased from 1948 to 1980. Woodland showed the greatest proportional loss. Increases in cultivated hectarage from 1948 - 1980 were predominantly at the expense of woodland and to a lesser extent, pasture and wetland from 1948-1980.

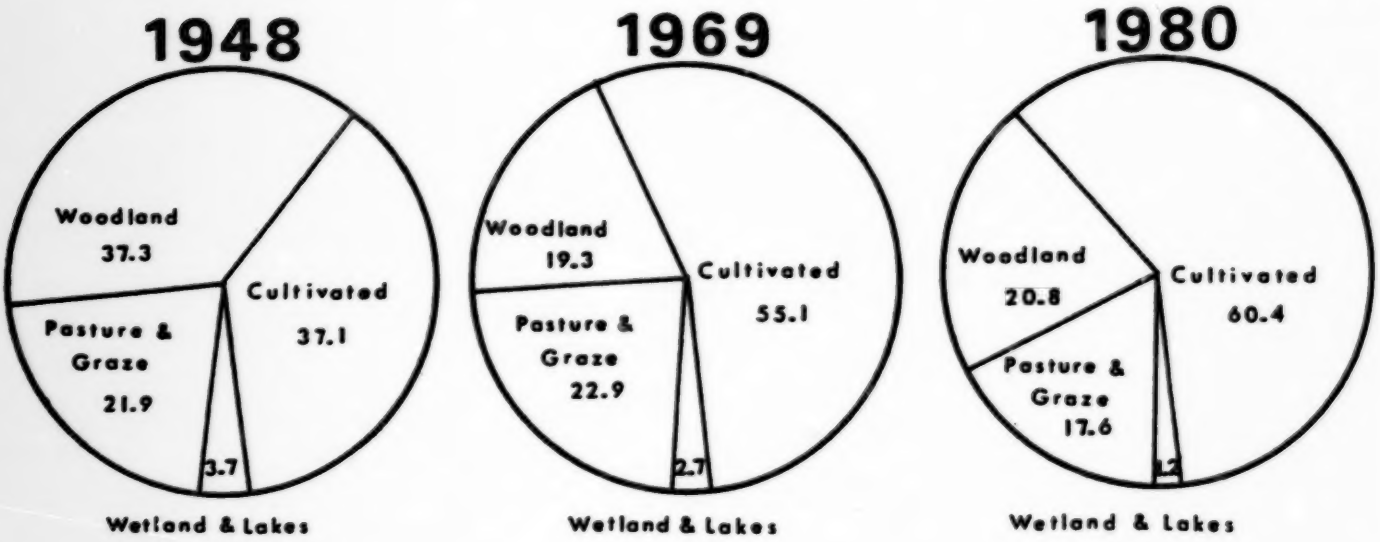


FIGURE 6 PERCENTAGE OF TOTAL STUDY AREA OCCUPIED BY EACH COVER TYPE BY YEAR

4.2 Mapping Accuracy Assessment

The accuracy of the air photo interpretation was calculated to average 95% for all classes and was based on the interpreters' common agreement on each land use class within the test area. Most problems were encountered in separating rough graze from pasture.

Two techniques were used for accuracy assessment of the digital analysis. The first involved generating correlation (confusion matrices) for the classification results. That task was accomplished by establishing check training areas (7% sample) within the digital data using the interactive training program and confirming the exact cover type from aerial photography. The manual theme generation program was then used to fill in those training areas with pure theme pixels which should have been the result arising from the supervised classification. A theme-compare program was then run which assessed the classification themes against the manually assigned pure theme files for the established training areas. These results were printed in a confusion table from which commission and omission errors are assessed (Table 2).

Kalensky et al (1981) noted that there is a lack of unanimity in interpretation of classification results from digital processing and particularly in calculation of classification accuracies. The correlation (confusion tables) are often used as the sole criterion for accuracy. However, rathan than exact classification accuracy, they express how similar the training areas (used for generation of classification statistics) are to check training areas (used for the accuracy evaluations). Obviously, some bias may be involved in locating check training areas as in locating of classification training areas. For example, in the case of large lakes, the operator may place a large check training area in the centre of the lake without coming into contact with the shoreline. The confusion matrix may then show 100% accuracy for lakes but it will not take into account shoreline edge pixel problems which may alter the true size of the lake.

TABLE 2 : CONFUSION MATRIX FOR CLASSIFICATION ACCURACY ASSESSMENT

Manual theme file: DHPTTTEST Classification theme file: DHPTTGOOD

	AGRICULTURE	WOOD	FALLOW	PASTURE	GRAZE	WETLAND	WATER	URBAN	TOTAL	%ACCURACY
AGRICULTURE	39699	297	576	339	2184	0	0	0	43095	92%
WOOD	69	39727	63	141	623	99	94	0	40816	97%
FALLOW	276	77	9099	30	52	0	0	0	9534	95%
PASTURE	111	57	0	3723	346	0	0	0	4237	87%
GRAZE	349	507	0	443	9651	0	0	0	10950	88%
WETLAND	24	8	81	2	0	2706	64	0	2885	93%
WATER	0	12	83	0	0	0	21627	0	21722	99%
URBAN	11	0	0	0	0	0	0	839	850	99%

Total number of classification pixels = 2052050

Total number of pixels used for accuracy assessment = 134089
(Manually classified in check training areas)

Horizontal axis: classifier theme files

Vertical axis: manually classified check training areas

Because the study involved the comparison of area-change statistics of each cover type for three years of data, another method of assessment was employed to determine mapping accuracy. That procedure involved photo interpreting 10% of the study area on the 1981 aerial photography, planimetering those results and then comparing them to the LANDSAT classification area calculations. The technique does not indicate the errors of commission or omission. Because the digital data were from 1980 and the air photo check data were from 1981, cropland and fallow classes are combined for accuracy assessment purposes in recognition of rotation practises (Table 3).

TABLE 3

DISCREPANCY ASSESSMENT OF DIGITAL ANALYSIS

Percent discrepancy of digital classification compared to air photo classification

	Cropland & Fallow	Woodland	Pasture	Rough Graze	Wetland	Lakes	*Urban
% discrepancy	+ 3.1%	+ 6.0%	+ 7.0%	+ 5.5%	- 19.0%	- 31%	0%
% agreement	96.9%	94.0%	93.0%	94.5%	81 %	69%	100%

*Manual theme

The average digital data correlation with the 1981 aerial photography measurements was 90% for all classes. Lakes and wetlands were underestimated by digital analysis in the planimetry accuracy assessment. That was understandable because the digital image was from the fall, while the aerial photography was taken in spring. Many lakes in the check areas were shallow and intermittent, thus were considerably smaller in the fall. Not surprisingly, lakes and wetlands scored better in the first accuracy assessment method using interactive training and the generation of a confusion matrix. That was due to the inherent bias in delineating lakes and wetlands which were obvious on our digital image when outlining the check training areas.

4.3 Labour and Costs

Parallel mapping projects, using both digital and airborne data, were conducted to assess land use of a common area. That procedure provided an opportunity to compare the costs of the two methods. Records of person days spent on each project and material costs were maintained (Table 4).

The comparison indicated a considerable saving of both time and money in favour of digital vs. airborne techniques for land use mapping (Table 4). It must be noted that existing photography was used for the 1948 and 1969 mapping and that those data acquisition costs were not included in the cost comparison. Also shown are the estimated mapping costs by air photo methods for a hypothetical mapping project for the same area if it had been custom flown with new airborne data. That is often a requirement when performing current land use studies. The cost comparison excludes hardware depreciation, maintenance and other overhead. It should be noted that the digital analysis system represents a considerably larger investment than the equipment used for our aerial photography interpretation. However, because the digital analysis equipment was on loan and no policy was in place for it to be amortized, those additional cost figures could not be built into the cost comparison. However, approximately 100 hours of computer time were utilized, of which 50% was used for geometric corrections and sub watershed area calculations. Assuming a cost of $50.00 per hour for the image analysis device including the operator, the cost for mapping via this technique would be $3.08/km^2.

TABLE 4

COST AND TIME COMPARISON OF DIGITAL VS AIR PHOTO MAPPING TECHNIQUES

Technique	Person Days Required	(1) Labour Cost	Material Cost	Total Cost	Cost of Mapping/km^2
1948 photo	141	$14,100	$ 950	$15,050	$ 8.43/km^2
1969 photo	102	$10,200	$ 600	$10,800	$ 6.05/km^2
1980 digital	22	$ 2,200	$ 500	$ 2,700	$ 1.51/km^2
Hypothetical new photo	102	$10,200	$7,900	$18,100	$10.13/km^2

(1) Estimated minimum

(2) Estimated cost of new, custom flown photo survey scale 1:50,000 based on recent I.C.A.P. average figures.

5. DISCUSSION

5.1 Physical and Biological Effects of Land Use Changes

Land clearing and wetland drainage has had a profound effect on the hydrologic regime of the Valley River. Analyses of the water flows indicated that the average spring peak discharge currently in the Valley River has almost doubled from the discharges recorded between 1913-1928 (Fig. 7). In addition, the attenuation of flows after peak discharge has increased. The rapid flushing of the Valley River now is probably due to the loss of woodlands. Wooded land would retain the snow for a longer period in spring, thus prolonging the snow melt period and consequently providing lower peak flows and a gradual decline in flows after peak. Also, wetlands and swamps would act as water storage reservoirs, buffering the amplitude of extreme flows.

Higher stream discharges and increased bed and streambank erosion, can cause increased sedimentation of bottom substrates. Accumulation of sediment can cover suitable spawning substrates or suffocate incubating fish eggs.

Rapid attenuation of flows after spring peak discharge results in low flows during walleye spawning and/or incubation periods. This would be critical in low-flow years and can cause the eggs to be de-watered, or subjected to wide fluctuations in water temperatures. In addition, newly-hatched walley larvae may be stranded in the river proper, where, if preferred food is limited, survival would be reduced.

The Valley River has higher peak flows now, with probably more streambank erosion, but its sediment load per unit of watershed area is the least of all the Dauphin Lake tributaries (Penner 1982). It is believed that the other tributaries of Dauphin Lake have higher sediment loads as well as lower walleye spawning success primarily because of stream channelization and extensive drainage improvements of adjacent wetlands. For example, channelization has resulted in increased soil erosion on the Wilson River (Fig. 8A & B). Figure 8A (1948 photo) shows channel dredgings between river bends and Figure 8B shows the devastating results. Many sharp bends near the dredging locations and other bends are completely eroded away, probably brought about by the increased speed of water flow. The overall river distance between points A and B has been reduced by 51%.

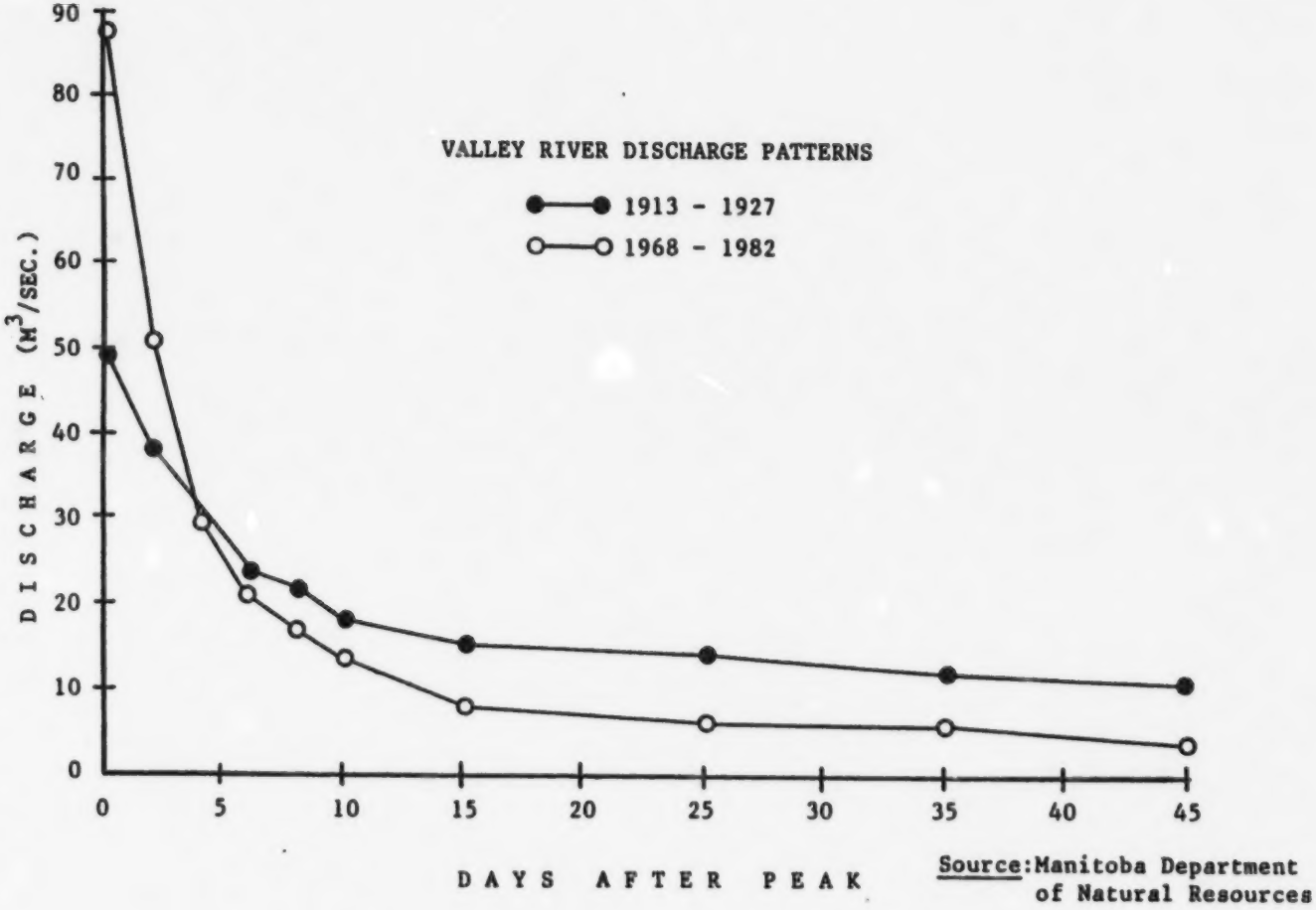


FIGURE 7: Valley River discharge patterns

FIGURE 8A 1948 photo of Wilson River showing dredging in the circled areas

0 1 km

FIGURE 8B 1981 photo of Wilson River showing erosion effects of channel dredging

0 1 km

The results of erosion and deposition from agricultural runoff are well demonstrated at the mouth of Edwards Creek Drain which flows into the Southwest corner of Dauphin Lake. The drain was built circa 1949. Air photo Figure 9A shows the mouth of the drain in 1950, just after construction. Air photo Figure 9B (1962), shows the enormous sediment delta which had been deposited in only 12 years.

Penner (1982) calculated that most of the large sediment deltas in Dauphin Lake were formed in the last 400-600 years while the lake itself was formed 8,000 years B.P. Those calculations were based on linear regression techniques of sediment data collected over the past 50 years. This suggests a link to agricultural clearing and de-forestation as a major contributing factor to this erosion rate. By the late 1800's agriculture was already well developed in the area. Unfortunately, the earliest aerial photography available was from 1948 so that it was difficult to determine the extent of these large delta formations and sediment inwash rates prior to the start of agricultural development.

Barto (1978) referred to mountain subdivisions of the Western Uplands as areas of high susceptibility to water erosion and extremely sensitive to any attempts to improve drainage. He wrote: "Problems associated with run-off and ground-water originating on the escarpment have caused concern since development of land along the base in the late 1800's. The problems are flooding, channel erosion and sheet erosion of excellent top soil."

The major negative impacts of channelization and sedimentation on walleye spawning success may include:

1) the elimination of historic spawning areas through channel straightening or removal of spawning substrates,
2) a greatly increased flushing rate of water in spring with very little flow soon after peak discharge, and
3) the siltation of bottom substrates/eggs.

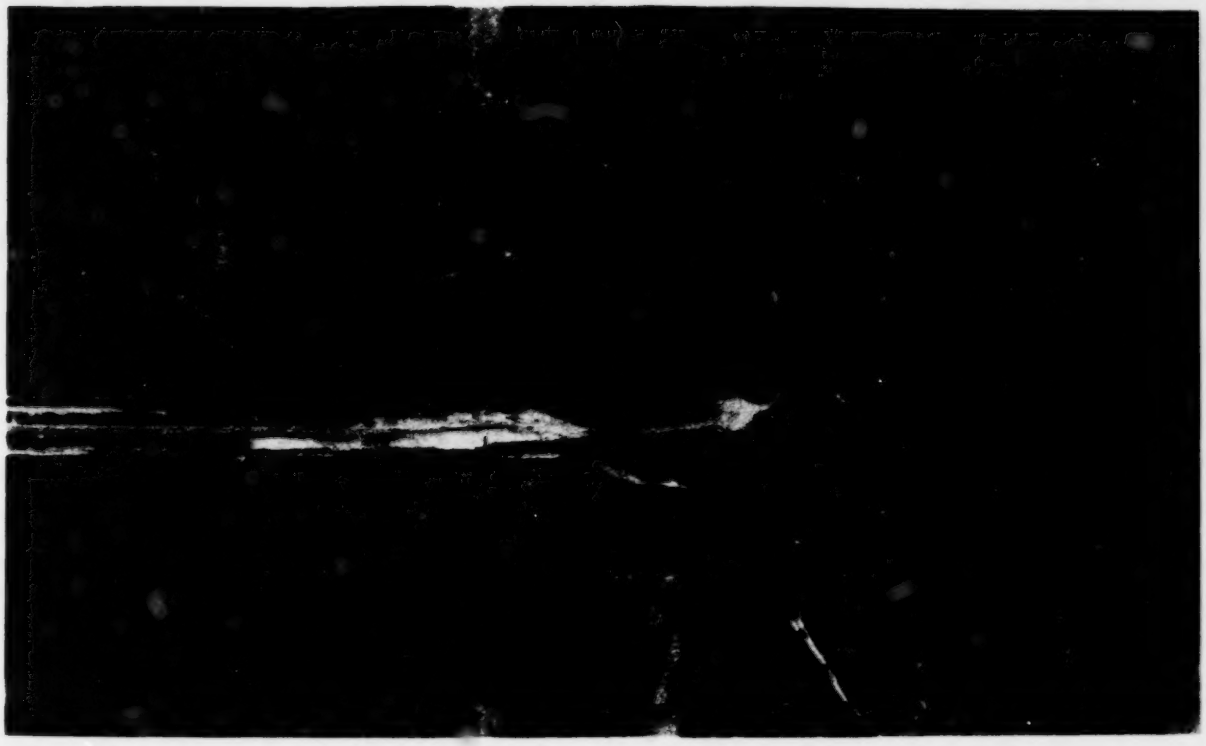


FIGURE 9A 1950 photo of Edwards Creek Drain just after construction

0 1 km

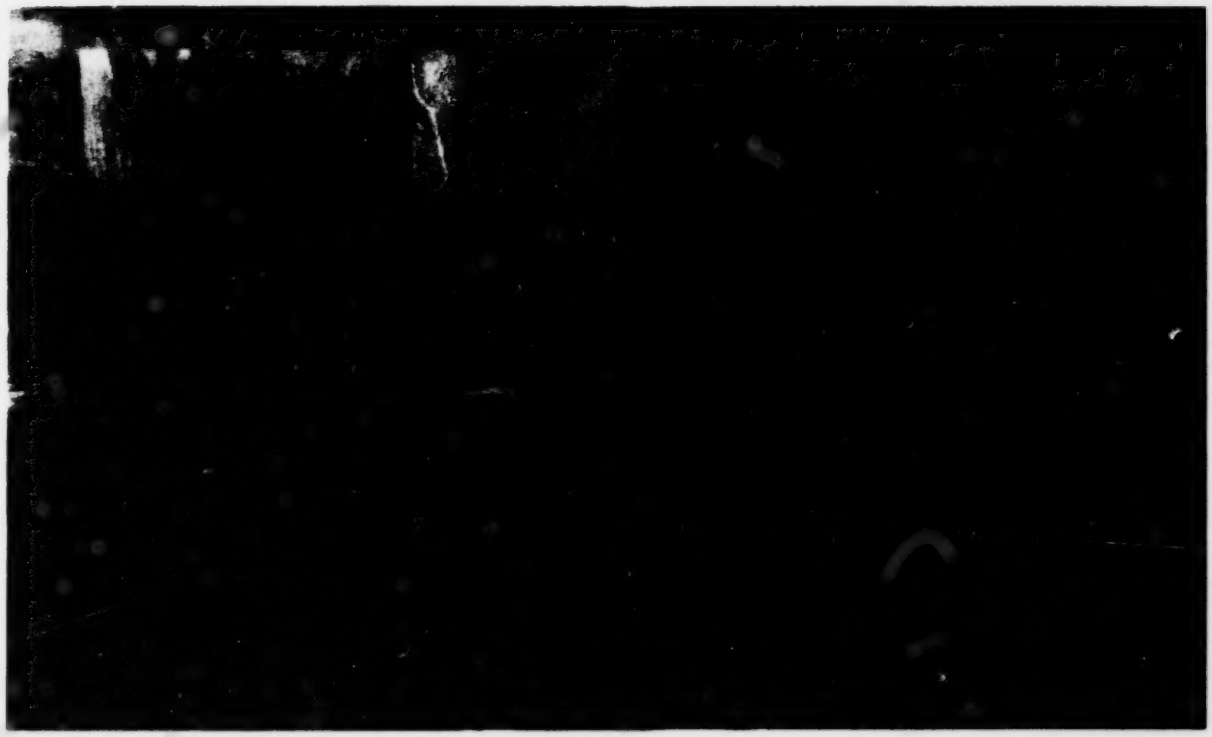


FIGURE 9B 1962 photo of Edwards Creek Drain showing deposition of sediment delta

0 1 km

Improper culvert crossings which impede walley spawning migrations have been, on several occasions, a significant factor reducing spawning success. Walleye which cannot reach traditional spawning areas, where preferred substrates, water flows and depths exist, may not spawn in a given season or alternatively may spawn on sub-optimal substrates. The latter results in a reduced egg survival.

Other factors, not examined to date, may contribute significantly in restricting the size of the walleye population of Dauphin Lake. These include commercial and sport exploitation, physico-chemical conditions in the lake proper, and other land use activities. (Table 5).

Table 5 . Effects of various land use activities in small watersheds on fish and fish habitat.

Near Stream Activity	Negative Physical Effects	Negative Effects On Fish In Streams and Lakes
Removal of Shoreline Vegetation	Increased bank erosion	Sedimentation of spawning grounds and suffocation of eggs Sedimentation of invertebrate fauna on stream bottom
	Increased water temperature	Sub-optimum temperatures for coolwater fishes
Wetland Drainage and Stream Channelization	Reduction in wetland areas/peripheral marshes Lower water table Increased peak rates of flow in spring with reduced summer flows	Loss of spawning and nursery areas Reduction of food source
	Changes stream substrates See: Removal of Shoreline Vegetation	Reduction of stream habitat during the summer
Land Clearing and Cultivation	Increased surface run-off in spring with rapid attenuation of flows after peak discharges	For spring spawners: reduction in available spawning areas and incubation success Increased transport time of passive larvae to suitable nursery areas
	Increased wind and water erosion	Increased sedimentation Increased lake eutrophication from fertilizer use Sub-lethal and toxic effects from chemicals (eg. pesticides)
	See: Removal of Shoreline Vegetation and Wetland Drainage	
Livestock Operations	Shoreline trampling causing bank slumping/erosion	Sedimentation of stream substrates
	Manure input to streams	Lake eutrophication
	See: Removal of Shoreline Vegetation	
Instream Obstructions (ford and culvert crossings, and water supply dams)	Local increased water velocities and/or turbulence	Partial or total blockage of fish movement
	Impassable barriers	Reduction in access to fish habitat and spawning areas
Roads	Bank de-stabilization and erosion Sediment from roadside ditches	Sedimentation of stream substrates
	See: Removal of Shoreline Vegetation	

6. CONCLUSIONS

Because agriculture represents the major economic resource in the study area, it is likely that further land clearing will continue but at a decelerated rate as the best land has already been developed. With the advent of much larger farm implements and through economic incentives, land owners were observed to be clearing considerable amounts of land close to tributary edges and clearing small bluffs and unproductive potholes.

The research project demonstrated that:

1. Improper land management was detrimental to the land base in the study area.
2. Land clearing apparently altered tributary flow regimes which may have affected fish habitat.
3. Classification of LANDSAT multispectral images can provide useful, up-to-date and location-specific data on present land use/land cover for agricultural and fisheries resource management personnel.
4. Digital analysis of LANDSAT is fast, accurate and very cost effective (excluding hardware costs) as compared to airborne mapping techniques.
5. By using digital analysis classification results can be tabulated within any desired mapping polygon through ARIES.
6. Hard copy classification results from LANDSAT can be provided to the resource manager in the form of color coded, thematic maps in a variety of scales.
7. The Technology Enhancement Program was successful in providing an opportunity for personnel of the Manitoba Remote Sensing Centre to become qualified operators and knowledgeable in digital analysis equipment.

7. RECOMMENDATIONS

Many land use practises were observed in the study area which may be seriously contributing to the degradation of the fishery resource and the land base as a result of surface run-off and stream channelization. The following measures are recommended as necessary to impede further deterioration:

1. An awareness campaign on soil erosion should be initiated in the Dauphin area to highlight the effects of land clearing in steep topography and along river shorelines, and the effects of channelization on streams.
2. The proposal concerning Surface Water Quality Objectives and Stream Classification for the Province of Manitoba (Revised Edition, 1979) compiled by the Clean Environment Commission should be enacted. One of the water quality objectives in this proposal is: "The quality of waters should be maintained so as not to impede optimum sustainable economic yield of Manitoba's fishery resources compatible with other desired uses of water."
3. A watershed management district similar to that established for the Whitemud River district should be established. This new district would have a board of directors who would employ integrated watershed management practises. This board should monitor land use changes and be assigned the authority to prevent potentially damaging channelization and river bank land clearing.
4. Past damage along river courses should be assessed for the degree of erosion to present. Remedial measures, including replanting of grass and/or trees, should be undertaken where feasible.

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APPENDICES

APPENDIX I

MEMORANDUM OF UNDERSTANDING

Between

The Department of Natural Resources
of the Government of Manitoba

and

The Department of Energy, Mines and Resources
of the Government of Canada

for

COOPERATION IN REMOTE SENSING

ARTICLE I. Scope and Objectives

The Department of Natural Resources of the Government of Manitoba (hereinafter referred to as DNR) and the Department of Energy, Mines and Resources, Government of Canada (hereinafter referred to as EMR) hereby state their intention to pursue scientific and technical cooperation in remote sensing in accordance with this Memorandum of Understanding (hereinafter referred to as "Memorandum") which establishes the procedure for cooperation.

The purpose of this Memorandum is to establish a framework for enhancing the scientific and technical capabilities of the Government of Manitoba in the application of remote sensing technology to natural resource management activities. EMR and DNR (hereinafter referred to as Parties) will undertake to implement a joint technology enhancement program as described in Schedule A. It is understood that EMR may include the cooperation of personnel from other federal government departments to provide specific scientific and technical capabilities pertinent to the projects being undertaken in the program.

ARTICLE II. Responsibility of the Parties

EMR will use its best efforts to: (i) have available for consultation a remote sensing specialist during the term of this Memorandum to assist provincial personnel engaged in demonstration projects; and (ii) provide training to provincial personnel in the use of the image analysis system lent to DNR. In addition, EMR will use its best efforts to give priority consideration for the use of image analysis facilities and remote sensing aircraft of the Canada Centre for Remote Sensing during the term of this Memorandum for the purposes of this cooperative endeavour.

DNR will endeavour to: (i) provide office accommodation for federal personnel engaged in the program; (ii) schedule, operate and maintain the image analysis system in accordance with the loan agreement, and (iii) coordinate the activities of provincial agencies involved in the demonstration projects.

The Parties will jointly define the objectives, resource requirements, and criteria for evaluation of specific demonstration projects. Changes to project design or the initiation of new projects will be undertaken only after consultation between designated representatives mutually acceptable by the Parties. Responsibilities of the Parties are detailed in Schedule A.

ARTICLE III. Source of Funding

Cooperative activities under this Memorandum will be subject to, and dependent upon, the financial support and manpower available to the Parties. Each Party will pay all operating expenses of its employees engaged in the program. DNR will use its best efforts to acquire satellite and airborne remote sensing imagery required for the projects, from Canada in accordance with its standard rates and to provide office accommodation for the program in Winnipeg.

ARTICLE IV. Review of Activities

The technology enhancement program established by this Memorandum will be monitored and evaluated by interdepartmental committees at the federal and provincial level. A federal Technology Enhancement Review Board, chaired by EMR, includes representatives of Agriculture Canada and Environment Canada. A provincial Advisory Committee, consisting of directors of the branches of provincial departments involved in the demonstration projects, will make recommendations to DNR on the nature of a provincial follow-on program when this Memorandum expires.

AGRICULTURE (CROPS)

WOODLAND

SUMMER FALLOW

PASTURES

ROUGH GRAZE

WETLANDS

LAKES

URBAN

VALLEY R. WATERSHED

LAND CAPABILITY BASED LAND USE/LAND COVER
DERIVED BY SATELLITE REMOTE SENSING CENTRE

SCALE 1:250 000

APPENDIX II

POOR

QUALITY

ORIGINAL